Prospective Study of Pneumonia Hospitalizations and Mortality of U.S. Older People: the Role of Chronic Conditions, Health Behaviors, and Nutritional Status

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Portions of the paper were presented at the 21st Annual Meeting of the Society for Epidemiologic Research, Vancouver, BC, Canada, June 14-17, 1988.

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Synopsis

Mortality and hospitalization rates for pneumonia have increased among older Americans during recent years (1979-86), despite a national commitment to the reduction of premature deaths from pneumonia. A prospective study of deaths and hospitalizations attributable to pneumonia was conducted among 5,474 subjects ages 55 and older who participated in the NHANES I Epidemiologic Followup Study. Prevalent chronic conditions, health behaviors, and nutritional status indicators, measured at baseline, were examined in relation to pneumonia hospitalization and death during 12 years of followup.

Mortality and hospitalization rates for pneumonia were higher among men than women, and higher among those ages 65 and older than among those 55-64 of both sexes. Risk of pneumonia death was higher among subjects with a history of congestive heart failure, stroke, cancer, or diabetes. Risk of pneumonia hospitalization was higher among subjects with a history of chronic obstructive pulmonary disease and among men who were current smokers. Daily alcohol consumption did not increase risk of pneumonia in this study population.

Four measures of nutritional status were examined taking age, prevalent chronic conditions, and cigarette smoking into account: body mass index, arm muscle area, and serum albumin and hemoglobin levels. Risk of pneumonia death was 2.6 times higher in men in the lowest quartile, compared with men in the highest quartile, of body mass index. Similarly, the risk was 4.5 times higher among men in the lowest quartile of arm muscle area. Risk of death from pneumonia was 3.6 times higher among women in the lowest quartile of serum albumin levels compared with women in the highest quartile. Relative risks for these nutritional status indicators remained elevated after adjusting for age and the medical history risk factors.

These risk factors should be taken into account when designing and evaluating pneumonia vaccination trials and community prevention programs.

PNEUMONIA AND INFLUENZA infections are the fifth leading cause of death among Americans ages 65 and older, accounting for more than 60,000 fatalities in 1986 (*1*). Death rates from these infections have increased during recent years (1979-86) in all age groups over 65, in marked contrast to persistent declines in rates of total mortality (*1*). Rates of discharge from hospitals with pneumonia as the primary diagnosis have also increased during recent years in this age group (*2*). More than 4.4 million days of hospital care were delivered to persons ages 65 and older with pneumonia in 1987 (*3*), a rise from 3.7 million days in 1984 (*2*). These increases are particularly disturbing because they have occurred during a time of national commitment to the reduction of premature deaths from influenza and pneumonia in adults, a goal explicitly stated by the Surgeon General in 1979 (*4*).

Despite the acknowledged public health importance of pneumonia morbidity and mortality, information on incidence rates and risk factors for

pneumonia in older Americans is sparse. Many studies that have identified risk factors for pneumococcal infections have done so among selected groups of infected hospitalized or institutionalized older adults without definition of the population at risk and often without comparisons to infection-free controls (*5–8*). Most available risk factor studies have been limited to investigation of underlying chronic conditions in these special populations and have not considered behavioral, nutritional, or other host susceptibility factors. We know of only one other study of rates and risk factors for pneumonia infections among noninstitutionalized older persons; it was based on a high-risk population of clinic attenders and was restricted to older men (*9*).

Much pneumonia morbidity and mortality may be preventable (*10*). An important step towards individual-level interventions and towards designing effective community vaccination programs is the identification of subgroups of community-dwelling older persons at high risk for pneumonia. Recent reviews have pointed to the need for epidemiologic risk factor studies that include the investigation of chronic conditions and nutritional status risk factors (*11,12*). A prospective study of a national cohort of community-dwelling older people provided the opportunity to investigate the relationships of chronic conditions, health behaviors, and nutritional status indicators to the risk of pneumonia hospitalization and mortality during 12 years of followup.

Methods

Study population. The study population was part of the First National Health and Nutrition Examination Survey (NHANES I) Epidemiologic Followup Study (NHEFS) conducted by the National Center for Health Statistics, a prospective study of 14,407 participants aged 25 to 74 years who were first examined at the NHANES I baseline in 1971–75. The NHANES I was based upon a clustered, multistage, stratified, probability sample of 23,808 subjects aged 1 to 74 years, representative of the noninstitutionalized civilian U.S. population. The design included oversampling of subgroups with special nutritional concerns including children, the elderly, women of childbearing age, and persons residing in poverty areas. Medical history, dietary, anthropometric, hematologic, biochemical, and examination data were collected at the baseline. Between 1982 and 1984, eligible subjects were traced for vital status. A reinterview was conducted with living subjects in their current residence, and a proxy informant was interviewed for subjects who were deceased or incapacitated. Vital status was successfully determined for 93 percent of the eligible cohort and, for those subjects traced, reinterviews were conducted among 93 percent of the living and by proxy for 84 percent of the deceased. Details of the design and data collection procedures utilized in the NHANES I and NHEFS have been described elsewhere (*13–17*).

The study population for this investigation included 2,605 men and 2,869 women aged 55 and older who were initially examined in NHANES I. Of the 5,677 eligible subjects in this age range, vital status was ascertained for 96.4 percent (all but 203 subjects). The only subjects excluded from all analyses were those lost to followup. The length of followup for subjects was variable ranging between 7 and 12 years; the average length was 10 years.

Pneumonia-related mortality and hospitalization. A total of 1,019 men and 679 women died in the interval between the initial interview and the followup survey. Discharge records were obtained for hospital and nursing home admissions during the interval when evidence of an admission was reported during the reinterview. The International Classification of Diseases, 9th revision, Clinical Modification (ICD-9-CM) was used to code both causes of death and discharge diagnoses. Pneumonia deaths were recorded as ICD-9-CM 480–486 for 136 decedents. Pneumonia deaths included those with pneumonia listed as an underlying, immediate, or contributing cause of death on the death certificate. Pneumonia was recorded as the underlying cause of death in 28.7 percent of these cases. Deceased subjects (37 men and 39 women) for whom no death certificate was obtained contributed person-years until the time of death and were assumed to have died without pneumonia listed as a cause of death. The results presented were not changed by exclusion of decedents with missing death certificates.

Rates of pneumonia hospitalization were based on 4,949 NHEFS subjects for whom interviews were obtained at followup (1982–84). Noninterviewed subjects were excluded because information about interim hospitalizations was not provided by these participants (267 men and 258 women). Evidence of pneumonia was ascertained from discharge records for 348 participants (337 from hospitalization records and 11 from nursing home records). The few cases of pneumonia identified

from nursing home records will henceforth be included with pneumonia hospitalizations in this report. Although repeated admissions for pneumonia were possible, analyses were based upon the first documented episode and date of that episode. Therefore, in this report rates refer to cumulative incidence rates, rather than attack rates, of pneumonia.

The sensitivity of the results presented on pneumonia hospitalization to the exclusion of noninterviewed subjects was evaluated in two ways. First, baseline demographic characteristics and chronic conditions were compared for the interviewed and noninterviwed groups. The noninterviewed group was slightly older on average and had a greater proportion of black men and women than the interviewed group, consistent with descriptions previously reported (*17*). No significant differences in prevalent chronic conditions at baseline were found between the interviewed and noninterviewed groups, except that history of stroke was more common among noninterviewed men (7.9 percent) than interviewed men (3.8 percent, $P<0.01$). Second, analyses of risk factor relationships with pneumonia hospitalization were repeated with the noninterviewed group included on the basis of two different assumptions about their pneumonia hospitalizations rates. For these analyses, noninterviewed subjects were first randomly assigned as cases or noncases, assuming a pneumonia hospitalization rate three times that of the interviewed group of the same sex and age. The analysis was repeated a second time assuming a rate in the noninterviewed that was one-third that of the interviewed group. Relative risks obtained from Cox regression coefficients under these two divergent assumptions (data not shown) were all well within one standard error of those presented in this paper for both men and women. The total number of hospitalization episodes missing in NHEFS is unknown, and therefore the impact of missing data cannot be evaluated completely (*16*). For some interviewed subjects, retrieval of hospitalization records was not complete due to refusal or inability of hospitals to supply information or refusal of the participant to authorize record retrieval. Therefore, the rates presented in this report should be considered conservative.

There was substantial nonoverlap in the two groups of pneumonia cases identified from death certificates and hospital records. Approximately 45 percent of deceased subjects with a pneumonia-related death had evidence of a pneumonia hospitalization prior to death (61 of 136 deaths). The discrepancy may be due, in part, to difficulty in obtaining accurate hospitalization reports from proxy informants of decedents at followup. Among subjects who were hospitalized with pneumonia, 11.5 percent died during the hospitalization with pneumonia listed as cause of death (40 cases), 6.0 percent died at a later date with pneumonia listed as a cause of death (21 cases), and 37.9 percent died of other causes by the end of followup (132 cases). Evidence of a nursing home stay during followup was obtained for 16.2 percent of cases of pneumonia death and 16.4 percent of cases of pneumonia hospitalization.

Data collection. Basic demographic information was collected at baseline on the age and race of respondents. A positive history for physician-diagnosed chronic conditions at baseline was ascertained by interview for the following conditions: chronic obstructive pulmonary disease (chronic bronchitis or emphysema), tuberculosis, chronic cough, heart attack, high blood pressure, congestive heart failure, stroke, diabetes, cancer, and hip fracture. Cigarette smoking (current, former, never) at baseline was only asked of a subset of the cohort in NHANES I. For the remaining subjects, cigarette smoking at baseline was ascertained using a retrospective smoking history collected at the NHEFS reinterview. An average measure of number of alcoholic drinks consumed per day at baseline was derived using three questions: "During the past year have you had at least one drink of beer, wine, or liquor?"; "How often do you drink?"; and "When you drink, how much do you usually drink over 24 hours?" A dichotomous measure, termed daily alcohol consumption, was used to compare those consuming one or more drinks per day with those consuming no alcohol or less than one drink per day on average. Less than 1 percent of subjects were missing data on any one of these variables. The only exception was data on cigarette smoking; 9.6 percent of subjects were not classified. Persons with missing values on any of the variables investigated were only excluded from analyses that involved those variables.

We also examined hospitalization during the followup period in relation to risk of pneumonia death. Six discharge diagnoses were examined: coronary heart disease (ICD-9-CM 410–414.9), hypertensive disease (401–405.99), congestive heart failure (428–428.9), cerebrovascular disease (430–438), diabetes (250–250.91), and malignant neoplasms (140–208.9). Subjects with one or more

hospitalizations for a particular condition, recorded in any order on the discharge summary list, were classified as hospitalized "cases" for that condition. We did not examine the relation between hospitalizations for these chronic conditions and hospitalization for pneumonia since any such association might well be influenced by Berkson's bias, a spurious association between two diseases among hospitalized cases that does not exist in the general population (*18*).

Previous reports have suggested that indicators of poor nutritional status, including low body mass, low body fat, low hemoglobin levels, and low serum albumin levels, are associated with increased risk of post-operative infections (*19–21*), impaired immune response (*22,23*), and infectious disease mortality (*24–26*). In this study, four baseline indicators of nutritional status were examined in relation to future risk of pneumonia. Two anthropometric measures, body mass index and arm muscle area, were calculated from measurements taken by trained technicians at the baseline examination (*27*). Body mass index was calculated as weight (kg) divided by height (meters)^2. Arm muscle area, an indicator of protein-energy malnutrition, is the estimated cross-sectional area of muscle at the midpoint of the upper arm corrected for triceps skinfold thickness using the following formula (*28*):

$$[\textit{Upper arm girth} - (\textit{pi} \times \textit{triceps skinfold})]^2 \div 4 \times \textit{pi}$$

Hemoglobin and serum albumin levels were determined using standard laboratory procedures performed at the Centers for Disease Control, Public Health Service. For each of the four nutritional status measures, we hypothesized that subjects with lower values would be at greater risk for future hospitalization or death attributable to pneumonia.

Statistical methods. Pneumonia mortality and hospitalization rates per 1,000 person-years of observation were computed for men and women separately (*29*). For each sex group, rates were also computed by age at baseline (55–64 years and 65 years and older).

The associations of baseline demographic, chronic condition, and health habit variables with pneumonia mortality and hospitalization were evaluated taking followup time into account with Cox proportional-hazards regression models using a two-step strategy (*30*). Separate analyses were conducted for pneumonia deaths and hospitalizations, because different risk factors may influence the occurrence of pneumonia at death and hospitalization with pneumonia before death. Analyses were also conducted for men and women separately. In the first step, each variable was entered into a Cox regression model adjusting for age alone. In the second step, all variables significantly associated ($P<0.05$) with the pneumonia endpoint, after adjusting for age, were entered into a multivariate Cox regression model. Estimates of relative risk (hazard ratios) and corresponding two-sided 95 percent confidence intervals were derived from the final Cox regression models. An analogous modelling strategy was used to evaluate the association of hospitalizations for chronic conditions during followup with risk of pneumonia mortality.

For each nutritional status indicator, subjects were divided into quartiles using sex-specific distri-

Table 1. Selected characteristics of subjects in the 1982–84 NHANES I Epidemiologic Followup Study, ages 55 and older at baseline, 1971–75

Baseline characteristic	Men (N = 2,605) Percent or mean	Men (N = 2,605) SD	Women (N = 2,869) Percent or mean	Women (N = 2,869) SD
Age (mean)	65.8	±5.4	65.9	±5.4
Race:				
White	84.0		84.4	
Black	14.7		15.3	
Other	1.3		0.3	
Cigarette smoking: [1]				
Current	28.4		16.5	
Former	29.8		8.5	
Never	29.7		67.8	
Daily alcohol consumption	21.1		7.1	
History of chronic conditions:				
Chronic obstructive pulmonary disease	11.3		9.0	
Tuberculosis	1.7		1.9	
Chronic cough	6.8		4.7	
Heart attack	12.4		7.1	
High blood pressure	29.6		44.6	
Congestive heart failure	3.0		3.3	
Stroke	4.2		4.1	
Diabetes	8.2		9.5	
Cancer	2.8		5.4	
Hip fracture	1.4		2.1	
Nutritional status indicators (mean):				
Body mass index (kg ÷ m^2)	25.3	±4.1	26.5	±5.4
Arm muscle area (cm^2)	61.4	±12.0	44.2	±12.5
Serum albumin (gm per 100 ml)	4.3	±0.3	4.3	±0.3
Hemoglobin (gm per 100 ml)	15.2	±1.4	13.8	±1.2

[1] Percents do not sum to 100 because of missing data on smoking for 12.1 percent of men and 7.2 percent of women.
NOTE: SD = standard deviation.

Table 2. Pneumonia mortality and hospitalization rates per 1,000 person years, NHEFS 1982–84, by sex and age at baseline

Sex and age at baseline	Mortality		Hospitalization [1]	
	Rate	Number of person years	Rate	Number of person years
Men	4.73	21,373	9.71	19,146
55–64 years	2.45	7,346	5.85	6,838
65 years and older	5.92	14,027	11.86	12,308
Women	1.35	25,990	6.89	23,506
55–64 years	0.46	8,662	4.21	8,081
65 years and older	1.79	17,328	8.30	15,425

[1] Excludes subjects who were not reinterviewed in NHEFS 1982–84.

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butions. Risk of pneumonia in the three lower quartiles was compared to risk in the highest quartile using binary indicator variables in Cox regression models, adjusting for age alone, and then for age and chronic conditions at baseline found to predict pneumonia in the previous step.

Although the analytic strategy was designed to test a priori hypotheses, and the number of variables studied was limited, our study was exploratory in the sense that it had multiple objectives and thus involved multiple comparisons. In lieu of arbitrary adjustments for multiple comparisons, the nominal *P* values have been presented for direct interpretation.

Results

Average age at baseline was approximately 66 years for both men and women (table 1). The cohort was 84 percent white, 15 percent black, and the remaining subjects (1 percent or less) were from other racial groups. Among men at baseline, 28 percent were current smokers, 30 percent were former smokers, and 30 percent had never smoked. In contrast, 68 percent of the women had never smoked. Only 17 percent of women were current smokers at baseline, and 9 percent were former smokers. Similarly, daily alcohol consumption on average was more frequent among men (21 percent) than among women (7 percent). Prevalence rates of physician-diagnosed chronic conditions (self-reported by subjects) at baseline were highest for chronic obstructive pulmonary disease, heart attack, high blood pressure, and diabetes. Less than 5 percent of men and women reported a history of tuberculosis, congestive heart failure, stroke, or hip fracture. On average, for the nutritional status measures, values of body mass index and serum albumin were similar for men and women, while women had lower average values for arm muscle area and hemoglobin.

Pneumonia mortality and hospitalization rates. Mortality rates (per 1,000 person-years) for pneumonia-related death were threefold higher for men (4.73) than women (1.35, table 2). This sex differential was also apparent within each age group. Within each sex group, rates were higher among older than younger subjects (table 2). The influence of age on risk was more dramatic for women than for men; mortality rates for older men were twofold that of younger men (5.92 versus 2.45 per 1,000 person-years), and rates among older women were fourfold that of younger women (1.79 versus 0.46 per 1,000 person-years). Hospitalization rates for pneumonia showed similar differences by sex and age. Rates were higher among men than women overall (9.71 versus 6.89 per 1,000 person-years) and higher among older than younger subjects regardless of sex (table 2).

Chronic conditions and health behaviors. History of congestive heart failure, stroke, and diabetes was associated with higher risk of pneumonia-related death in both sexes, although each of these associations was statistically significant in only one sex group in every case (table 3). Among men, chronic conditions that were risk factors significantly associated with pneumonia death were chronic cough, congestive heart failure, diabetes, and hip fracture; relative risks ranged between 2 and 3. Among women, history of stroke and cancer were both strongly and significantly associated with risk of pneumonia death. Baseline characteristics that showed no relationship to risk of pneumonia death in either sex after adjusting for age included race, current smoking, former smoking, and daily

Table 3. Relation of risk factors to pneumonia mortality, NHANES I Epidemiologic Followup Study

Risk factor	Men		Women	
	RR [1]	95 percent CI	RR [1]	95 percent CI
Age at baseline (10 year difference)	[2] 2.3	1.5–3.5	[2] 3.3	1.5–7.1
Baseline chronic conditions:				
Chronic obstructive pulmonary disease	1.5	0.9–2.7	0.7	0.2–2.5
Chronic cough	[3] 1.9	1.0–3.5	1.4	0.3–6.2
Congestive heart failure	[2] 2.9	1.3–6.2	1.4	0.3–5.9
Stroke	2.0	0.9–4.3	[2] 4.0	1.5–10.6
Cancer	1.5	0.6–4.2	[3] 2.9	1.1–7.6
Diabetes	[2] 1.8	1.0–3.3	2.0	0.8–4.9
Hip fracture	[3] 3.3	1.2–9.1	[4]	
Hospitalization with chronic conditions during followup:				
Congestive heart failure	[3] 1.8	1.1–3.2	[3] 2.7	1.2–6.1
Cerebrovascular disease	[3] 1.7	1.0–2.8	1.4	0.6–3.5
Cancer	[2] 1.9	1.2–3.2	[3] 2.6	1.1–6.0
Diabetes	1.5	0.8–2.6	1.5	0.6–3.6

[1] Relative risks computed from sex-specific multivariate Cox regression models based on pneumonia deaths of 101 men and 35 women. Relative risks for baseline chronic conditions are adjusted for age and all baseline chronic conditions shown. Relative risks for hospitalization with chronic conditions are adjusted for age and all chronic condition hospitalizations shown.
[2] $P<0.01$.
[3] $P<0.05$.
[4] Variable not included in final model due to limited dispersion. No cases of pneumonia-related death occurred among women with a history of hip fracture at baseline.
NOTE: RR = relative risk; CI = confidence interval.

Table 4. Relation of baseline risk factors to pneumonia hospitalization, NHANES I Epidemiologic Followup Study

Risk factor	Men		Women	
	RR [1]	95 percent CI	RR [1]	95 percent CI
Age (10 year difference)	[2] 2.1	1.5–2.8	[2] 1.7	1.3–2.4
Current smoking	[2] 2.0	1.3–3.0	1.3	0.9–2.0
Former smoking	1.4	0.9–2.0	1.6	1.0–2.6
Chronic obstructive pulmonary disease	[2] 1.8	1.2–2.8	[2] 2.0	1.3–3.1
Tuberculosis	0.3	0.0–1.9	1.4	0.6–3.5
Chronic cough	1.5	0.9–2.5	1.5	0.9–2.7
Heart attack	[3] 1.6	1.0–2.4	1.4	0.9–2.4
High blood pressure	1.1	0.8–1.5	[3] 1.4	1.0–1.9
Congestive heart failure	2.0	1.0–4.3	1.1	0.5–2.5
Diabetes	1.0	0.6–1.8	[3] 1.7	1.1–2.7

[1] Relative risks computed from sex-specific multivariate Cox regression models including all variables shown. Relative risk estimates are based on 166 pneumonia hospitalizations of men and 157 of women.
[2] $P<0.01$.
[3] $P<0.05$.
NOTE: RR = relative risk; CI = confidence interval.

alcohol consumption, and history of tuberculosis, heart attack, and high blood pressure.

For men and women, relative risks relating hospitalizations for major chronic conditions during the followup interval to pneumonia death were similar (table 3). Hospitalizations for congestive heart failure and cancer were significantly associated with a two- to threefold increased risk of pneumonia death in both sexes. Hospitalizations for cerebrovascular disease and diabetes during followup were modestly associated with increased risk of pneumonia death with relative risks ranging between 1.4 and 1.7 in both sexes. In general, the wider confidence intervals for relative risk estimates in women compared with men result from the smaller number of pneumonia deaths among women (35) than men (101). Despite this small number of pneumonia deaths of women, the relative risks presented from the multivariate Cox model are very similar to the relative risks obtained from age-adjusted Cox models that considered each chronic condition separately.

History of chronic obstructive pulmonary disease was associated with a doubled risk of pneumonia hospitalization for both sexes (table 4). Men reporting a history of congestive heart failure at baseline experienced nearly twice the risk of pneumonia hospitalization. Histories of chronic cough, heart attack, high blood pressure (women only), and diabetes (women only) were associated with increased risk of pneumonia hospitalization with relative risks ranging from 1.4 to 1.7. History of

Table 5. Age-adjusted relative risks for pneumonia mortality of NHEFS subjects according to nutritional status indicators at baseline

Nutritional status indicator	Men		Women	
	RR [1]	95 percent CI	RR [1]	95 percent CI
Body mass index (kg ÷ m^2):				
Lowest quartile	[2] 2.6	1.4–4.5	2.3	0.9–6.0
Second quartile	1.2	0.8–1.7	1.4	0.5–3.9
Third quartile	1.2	0.6–2.2	1.0	0.3–3.0
Highest quartile [3]	1.0	. . .	1.0	. . .
Arm muscle area (cm^2):				
Lowest quartile	[2] 4.5	2.2–9.0	1.4	0.6–3.4
Second quartile	[4] 2.4	1.1–4.9	1.2	0.5–3.0
Third quartile	[4] 2.2	1.1–4.7	0.7	0.2–2.0
Highest quartile [3]	1.0	. . .	1.0	. . .
Serum albumin (gm per 100 ml):				
Lowest quartile	1.3	0.8–2.2	[4] 3.6	1.1–11.5
Second quartile	1.3	0.7–2.2	2.4	0.7–7.7
Third quartile	0.6	0.2–1.3	2.1	0.6–6.9
Highest quartile [3]	1.0	. . .	1.0	. . .
Hemoglobin (gm per 100 ml):				
Lowest quartile	0.9	0.5–1.5	0.9	0.3–2.2
Second quartile	0.9	0.5–1.5	0.7	0.3–1.9
Third quartile	[4] 0.5	0.2–0.9	0.6	0.2–1.8
Highest quartile [3]	1.0	. . .	1.0	. . .

[1] Relative risks derived from Cox proportional hazards regressions models adjusting for age.
[2] $P<0.01$.
[3] Reference category.
[4] $P<0.05$.
NOTE: RR = relative risk; CI = confidence interval.

tuberculosis was associated with twice the risk of pneumonia hospitalization among women after adjusting for age alone, but this association was substantially diminished in the multivariate analysis. Histories of stroke, cancer, and hip fracture reported in the baseline survey were not related to pneumonia hospitalization in either sex, in marked contrast to the associations observed for these conditions with pneumonia-related mortality.

Cigarette smoking was associated with an increased risk of pneumonia hospitalization for both men and women; however, the association was stronger and statistically significant only for current male smokers (relative risk (RR) = 2.0, $P<0.001$; table 4). Race and daily alcohol consumption showed no relationship to pneumonia hospitalization.

Nutritional status. Age-adjusted relative risks relating four indicators of nutritional status to risk of pneumonia death are shown in table 5. Except where noted, the associations shown in table 5 for pneumonia death were consistent with the results relating these nutritional parameters to pneumonia hospitalization. Subjects in the lowest quartile of body mass index, compared to subjects in the highest quartile, had a greater than twofold risk of pneumonia death. Although this association was present for both sexes, the association was statistically significant only for men. This association among men was present and consistent when pneumonia hospitalization was considered; however, no association was observed between body mass index and pneumonia hospitalization for women.

Among men, a strong inverse relationship was observed between arm muscle area and risk of pneumonia death. Risks increased in a graded manner from the highest to lowest quartiles of arm muscle area (RRs = 2.2, in the third, 2.4 in the second, and 4.5 in the lowest quartile). The inverse associations of body mass index and arm muscle area with risk of pneumonia among men were present throughout the followup period, and they became stronger after the second year of followup (figs. 1 and 2). Furthermore, adjustment for the chronic conditions related to pneumonia did not diminish the consistency or strength of these associations (figs. 1 and 2). Statistical tests for trend in risk of pneumonia mortality across quartiles of body mass index and arm muscle area, based on the models presented in figures 1 and 2, were highly significant ($P<0.01$). No association was observed among women for arm muscle area and pneumonia death.

Women with serum albumin levels in the lowest quartile had three times the risk of pneumonia-

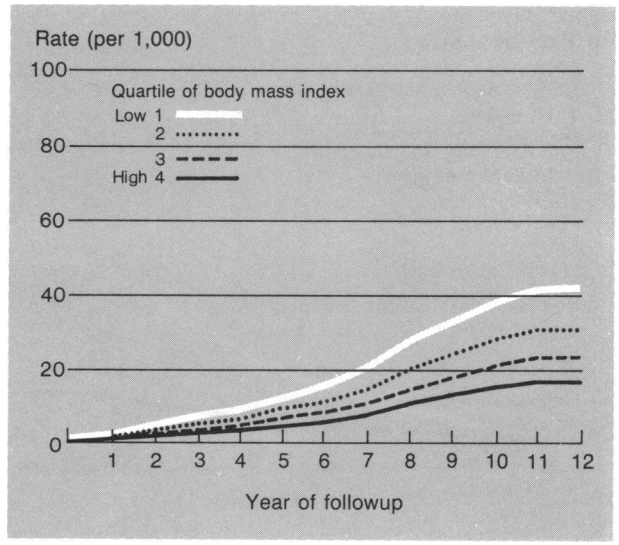
related death as compared with women in the highest quartile, and this association was also present and significant for pneumonia hospitalization. The association of pneumonia with low serum albumin in women was present throughout the followup period and remained significant after adjusting for the chronic conditions related to pneumonia (fig. 3). For the data presented in figure 3, the test for trend across quartiles of serum albumin was also statistically significant ($P<0.001$). No association between serum albumin and either pneumonia endpoint was observed for men. Low levels of hemoglobin were not associated with increased risk of pneumonia in either sex.

Discussion

The identification of subgroups of older persons at high risk for pneumonia is a prerequisite to effectively targeting preventive programs aimed at reduction of the morbidity and mortality associated with pneumonia. This investigation is particularly relevant to such objectives, in that risk factors were identified among a community-dwelling national cohort of older people followed prospectively for the occurrence of pneumonia-related deaths and hospitalizations. This study confirms higher rates of pneumonia hospitalization and death in men than women, and higher rates among older than younger subjects (*31*). No differentials in pneumonia risk were observed by race in this study or in a recent study of older men attending a Veterans Administration medical clinic (*9*). In Charleston County, SC, the incidence of pneumococcal bacteremia was found to be similar among black and "other than black" race groups for those subjects ages 60 to 69 and older, whereas a marked excess of pneumococcal bacteremia was observed in young and middle-aged black adults (*8*). In 1985, United States death rates for pneumonia were higher for black men and women than for white men and women through age 79, and lower among blacks at ages 80 and older (*32*). It was not possible to determine whether such a crossover in rates by race had occurred in this cohort because few participants in this study were followed beyond age 80.

Several studies have shown that older people with chronic conditions are at increased risk of developing pneumonia and have higher case-fatality rates after acquiring pneumonia. However, few studies have quantified these associations for specific chronic diseases (*5–8,33,34*). In this study, histories of several chronic conditions reported at baseline were found to increase risk of pneumonia

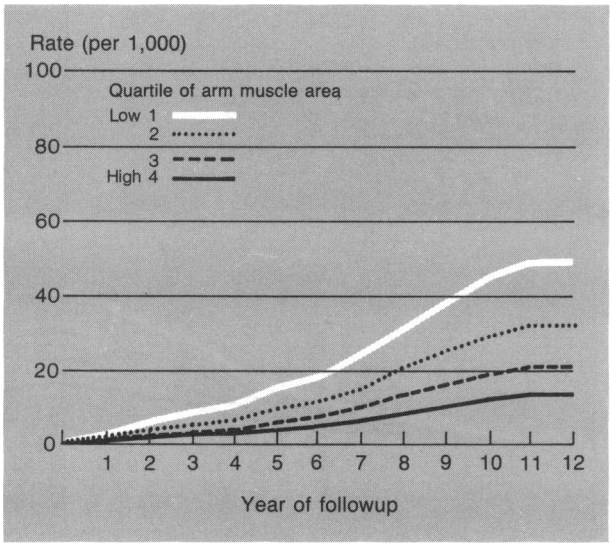
Figure 1. Pneumonia mortality rates (per 1,000) for men aged 55 and older at baseline according to quartile of body mass index adjusted for age, chronic obstructive pulmonary disease, chronic cough, congestive heart failure, stroke, cancer, diabetes, hip fracture, current smoking and former smoking



hospitalization and death. The most consistent associations among men and women were observed for congestive heart failure, stroke, cancer, and diabetes at baseline in relation to pneumonia death. Subjects who had been hospitalized for any of these conditions during the followup period were also at increased risk of pneumonia death, providing further evidence for the consistency of these associations. In addition, a history of chronic obstructive pulmonary disease was significantly associated with an increased risk of pneumonia hospitalization in this study for both sexes.

These findings are quite similar to the study by Lipsky and coworkers of pneumococcal pneumonia among older men attending a Veterans Administration medical clinic, the only other study we have found in which risk factors for pneumonia were investigated in a population of ambulatory older people (*9*). In that study, risk of pneumonia was increased among older men with a history of congestive heart failure, cerebrovascular disease, or chronic obstructive pulmonary disease, and among those who had higher annual hospitalization rates. Others have also shown that congestive heart failure and chronic obstructive pulmonary disease increase the risk of acquiring pneumococcal infections (*33,35*). The association of a history of diabetes (and hospitalization with diabetes) with risk of pneumonia in our study was not observed in the Veterans Administration medical clinic population. Although, our finding gains support from

Figure 2. Pneumonia mortality rates (per 1,000) for men aged 55 and older at baseline according to quartile of arm muscle area adjusted for age, chronic obstructive pulmonary disease, chronic cough, congestive heart failure, stroke, cancer, diabetes, hip fracture, current smoking and former smoking



other reports of an increased risk of pneumonia, and higher case fatality following pneumonia, among diabetics, the issue of whether diabetics are a high-risk group remains unclear (*36–38*). Dementia, seizure disorders, and residence in an institution were also identified as independent risk factors for pneumococcal pneumonia in the Veterans Administration clinic study. These factors could not be evaluated in our study since information was not available on the two chronic conditions, and all participants were community-dwelling at the time of the baseline examination. Information was not available on several other previously identified risk factors for pneumonia, including splenectomy and splenic disorders, cirrhosis of the liver, renal failure, and immunosuppressing conditions (*39*).

Risk of pneumonia was higher among cigarette smokers in this study, and the association was stronger for men than women. Similarly, current cigarette smoking was more strongly associated with pneumonia risk than former cigarette smoking in the study by Lipsky and coworkers of men attending a Veterans Administration clinic (*9*). Neither Lipsky's investigation nor our own analysis indicated any association between heavy alcohol consumption and risk of pneumonia. Although other studies have shown that alcoholics are particularly prone to pneumonia (*8,40*), the lack of a reliable measure of "alcoholism" in both of these studies may be one explanation for the disparity.

Pneumonia deaths and hospitalizations were investigated separately in this study because we suspected that pneumonia infections immediately preceding death would be likely to occur secondary to severe, fatal chronic conditions such as congestive heart failure or stroke. Pneumonia hospitalizations, the majority of which were nonfatal, may be more likely to result from habits and conditions that specifically increase vulnerability of the respiratory tract to infection (for example, cigarette smoking and chronic obstructive pulmonary disease). The findings that chronic obstructive pulmonary disease and current smoking (men only) were the major risk factors for pneumonia hospitalization, while congestive heart failure, stroke, cancer, and hip fracture (men only) were strongly related to pneumonia death, offer some support to these suspicions.

Several of the chronic conditions that increased the risk of pneumonia-related death could do so through compromising host physical defenses (*41*). For example, the increased risk of pneumonia death observed among subjects with congestive heart failure, stroke, cancer, and hip fracture (men only) may be partially a consequence of disability, immobility, and altered mental status caused by these conditions, in turn predisposing the person to dehydration, decreased clearance of respiratory tract secretions, and aspiration. Growth of bacteria in the lungs may be encouraged by conditions such as chronic obstructive pulmonary disease with impaired cough and diminished lung compliance, and in congestive heart failure in which alveolar fluid can accumulate and pulmonary hygiene is poor (*9,41*).

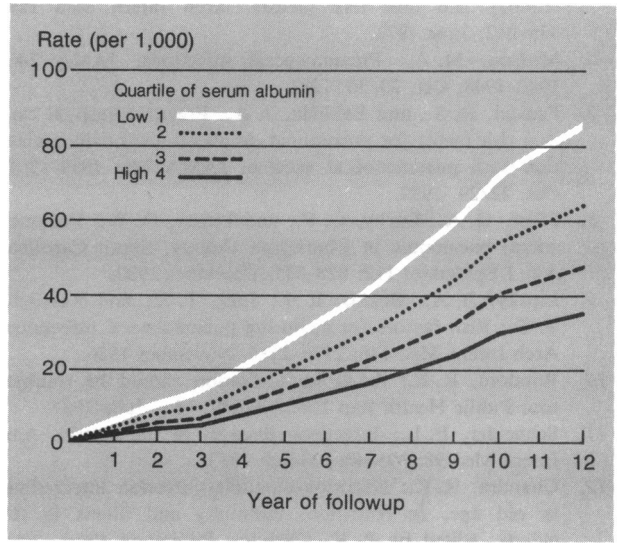
The risk of pneumonia was higher in this study among persons with low body mass index (men and women) and among those with low arm muscle area (men only). These associations were strong and statistically significant among men for both pneumonia endpoints (hospitalization and mortality), and the associations persisted throughout the followup period. Among community dwelling adults in Norway, low body mass index (less than 21 kg $\div$ m^2) was associated with increased mortality from tuberculosis and with higher incidence rates of tuberculosis (*24,25*). Low body fat, as indicated by radiographically measured skinfold thickness, has also been associated with increased mortality from respiratory infections including pneumonia, influenza, and tuberculosis (*26*). Among hospitalized patients, low body mass index and low midarm muscle circumference have been related to low levels of serum albumin, low lymphocyte counts, and impaired delayed hypersensi-

tivity responses (*22,23*). A plausible explanation for the relation of anthropometric nutritional status measures to pneumonia is that low levels of these parameters may indicate the severity of underlying chronic conditions. Muscle and connective tissues are catabolized during prolonged chronic illness stress, eventually leading to depleted skeletal muscle and visceral protein stores (*42*). Alternatively, these measures may be markers of subclinical underlying chronic conditions that had not yet been diagnosed at baseline.

Low serum albumin values were associated with increased risk of pneumonia mortality and hospitalization in this study among women only. The sex specificity of this finding was not expected and requires confirmation in future studies. Clinical studies have shown that low serum albumin is a marker of the burden and severity of chronic conditions among critically ill patients and a predictor of infections among patients undergoing surgery (*19–21,23*). Low serum albumin values have also been associated with impaired delayed hypersensitivity (*23*).

Surveillance of pneumonia events through ICD-9-CM coded diagnoses on hospital records and death certificates is an inherent limitation of our study. Although hospital discharge records have been shown to be a reliable source for surveillance of pneumonia diagnoses of patients admitted to hospitals (*43*), the use of these records implies the exclusion of pneumonia infections that occur among community-dwelling older people and are resolved within ambulatory care settings. Therefore, risk factors for pneumonia in our study may not be generalizable to pneumonia infections that do not result in hospitalization or death. It was not possible for us to determine whether diagnoses of pneumonia were accompanied by cultures of blood or sputum, whether the organism responsible for the pneumonia had been identified, or whether likely competing diagnoses such as pulmonary edema or embolism had been definitively ruled out. Of all hospitalized cases with a discharge diagnosis of pneumococcal pneumonia or lobar pneumonia (ICD-9 481) in Rhode Island in 1976, a record review showed that 84 percent of cases had evidence of infiltrate on chest X-ray, while only 22 percent of cases had both infiltrate on X-ray and positive blood or sputum culture for *Streptococcus pneumoniae (34)*. Antibiotic therapy prior to hospitalization can impair the identification of specific bacterial pathogens (*5*). Nevertheless, in spite of these limitations of clinical diagnosis, the findings of this study are quite consistent with previous studies, including those in which diagnoses of pneumonia were confirmed with cultures (*5–7,9*).

Figure 3. Pneumonia hospitalization rates (per 1,000) for women aged 55 and older at baseline according to quartile of serum albumin level adjusted for age, chronic obstructive pulmonary disease, chronic cough, congestive heart failure, tuberculosis, heart attack, high blood pressure, diabetes, current smoking and former smoking



Changes in rates of pneumonia hospitalizations and mortality are a major index for monitoring progress towards national objectives to reduce these infections in older Americans; therefore, a better understanding of risk factors for these events is needed. We found that medical history of specific chronic conditions, smoking habits, and simple measures of nutritional status can be used in populations of ambulatory older people to identify subjects at higher risk for subsequent pneumonia hospitalization and death. These factors appear to have predictive value even when measured years before the occurrence of pneumonia. Knowledge of these risk factors may be useful for targeting high risk groups and evaluating outcomes in vaccine efficacy trials and community prevention programs.

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